CTA Discussion Paper

Economic Impacts of Climate Change on Priority Value Chains in the Caribbean:

Implications for Private-sector Investment and Scaling-up of Climate-smart Agriculture in the Region

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Economic Impacts of Climate Change on Priority Value Chains in the Caribbean:

Implications for Private-sector Investment and Scaling-up of Climate-smart Agriculture in the Region

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Table of contents

Figures

Tables

Executive summary

To support the implementation of CTA's flagship project for the Caribbean, this report is aimed at developing capacity-building efforts for specific groups of farmers engaging in specific production activities in priority value chains so they may improve their access to key markets. This report focuses on the threats climate change poses to the production of two priority value chains in the Caribbean – fruit and vegetables, and roots and tubers. These two value chains are very important in terms of sustaining household food security and reducing poverty throughout the region, and provide an important source of income for thousands of smallholder and medium-scale farmers and their families. Any significant fallout in the production of either fruits and vegetables or roots and tubers could therefore stem, if not reverse, past efforts in reducing poverty in the region.

This report is informed by a detailed desktop review of available literature on current and potential climate change impacts on fruit and vegetable and root and tuber value chains in the Caribbean. The review was conducted between July and August 2016, and covered academic papers, technical reports and other available data sources containing relevant sector-specific information on the two value chains. Specific objectives of the research were to:

1. review available information to evaluate current and potential effects of climate change on fruit and vegetable and root and tuber value chains in the Caribbean;
2. identify the critical stages when the various actors (e.g., farmers, traders, processors) of the two value chains are most vulnerable to climate change and highlight how they are specifically affected;
3. identify financing and other mechanisms (if any) that are available to value-chain actors to enable them to respond to the critical and vulnerable phases of these two prioritised value chains;
4. identify the implications of the above for the development of targeted training and curriculum development, in particular, and scaling-up of climate-resilient solutions for fruit and vegetable and root and tuber value chains in general in the Caribbean.

The effects of climate change on Caribbean value chains

Considerable scientific evidence indicates that the Caribbean is already experiencing a changing climate regime. Since the 1950s the region's climate has gotten progressively warmer, with a marked increase in the number of very hot days and very hot nights across the Caribbean Basin. There is a general consensus within the regional climate science community that the regional climate will get progressively warmer and drier over the course of this century. In addition to these trends, there has been a marked increase in hurricane and tropical storm activities in the region since the mid-1990s, which may be linked to longer term anthropogenic climate change.

This report demonstrates that any significant fluctuations in the region's climate (especially in terms of mean surface temperature and rainfall) will have significant adverse effects on the region's agriculture sector and the millions of people who rely on the sector for a living. Predicted shortages in available water resources across the majority of the Caribbean and increases in evapotranspiration will present a direct challenge for the open-field rain-fed cropping systems that dominate the region's agricultural landscape. Added to this are the impending threats that extreme weather events, such as hurricanes, pose to agricultural production and farming infrastructure.

The root and tuber and fruit and vegetable value chains were found to be particularly susceptible to climatic shocks given these sub-sectors' sensitivity and exposure to a range of climate-related hazards. The impact of recent hurricanes, floods and droughts has illustrated this. Added to this, the projected long-term changes in temperature and rainfall are likely to have a negative effect on regional agricultural production if measures are not put in place soon.

When and how value-chain actors are at their most vulnerable

This report highlights that changes in the region's climate will affect various groups of value-chain actors more than others. The

large differences in vulnerability seem to be a function of an individual's position along the value chain (which, to some extent, determines their degree of exposure to climate-related effects), compounded by wider societal, cultural, agronomic and economic factors, such as gender, poor farming practices, limited access to climate-smart solutions and technologies, and disparities in wealth. Caribbean farmers are among the agricultural value-chain actors who are most vulnerable to climate-related effects given the nature of their farming systems and the socio-economic landscape in which they operate. The bulk of farmers in the Caribbean operate on small (sometimes fragmented) farm holdings and cropping systems are normally labour intensive and rain-fed. Additionally, many of these farmers operate with limited access to extension support services and financial assistance. As the climate becomes less predictable, these vulnerabilities are going to become more pronounced. Other value-chain actors, such as traders, distributors and agro-processors, are also vulnerable. In general, any disruption in local food production will result in the loss of income for farmers and other value-chain actors, and lead to an increase in food prices in the domestic markets, which poses a threat to regional food security.

In terms of policy, there is a wide array of past and ongoing regional policies and programmes that have direct linkages with agriculture and will likewise be influential in boosting the sector's capacity to mitigate and adapt to future climate change. Despite the strides made, asymmetries still exist among countries in terms of national, institutional and human capacities. One of the biggest challenges is the absence of accurate and up-to-date data on climate-related effects and sector-specific vulnerabilities.

Finance and other mechanisms enabling a response to climate change

This report highlights a number of funding sources available for climate change-related activities in the regional agriculture sector. A significant portion of these funds are available through multilateral financing mechanisms. With key institutions such as the Caribbean Community Climate Change Centre (CCCCC) and the Caribbean Development Bank (CDB) gaining accreditation with the Green Climate Fund, the region is now in a better position to increase its share of available global climate financing. Utilising climate finance effectively, however, requires strong regional and national institutions capable of efficiently deploying money and overseeing the implementation of high-impact initiatives. There is also a need to tap into other financial resources. The forging of bilateral agreements could provide useful assistance, for instance. A lot of opportunities for private-sector financing are available, including contributions from the regional business community and a number of international philanthropic organisations.

Targeted training and scaling-up of climate-resilient solutions

The final objective of this report was to identify the likely implications of the findings for the scaling-up of climate-adaptation solutions for the two regional priority value chains. Essentially, agricultural value-chain actors in the Caribbean face an uncertain future typified by heightened climatic risks. There is therefore an urgent need to identify and address the underlying causes of the sector's growing vulnerability to climate change. Although a number of climate-adaptation initiatives can be found throughout the region, the bulk of these are limited in both scale and scope. Training and curriculum development in the regional priority agriculture value chains must be targeted at the underlying vulnerability, and climate-resilient solutions and best practices scaled up where possible. The forging and strengthening of technical partnerships and cooperation on climate financing, science and innovation, capacity development, and the retrieval, monitoring and dissemination of relevant up-to-date and accurate scientific information are essential to building resilience and supporting climate-smart farming practices in the Caribbean.

Introduction

Objectives of the project

The vulnerability of the Caribbean to a changing climate is well documented in the scientific literature, especially within the context of Caribbean small island developing states (SIDS) and their relatively high sensitivity and exposure to both present-day and projected climate-change effects (see, for example, Cambers, 2009; Mimura *et al.,* 2007; Gamble *et al.,* 2010; Pulwarty *et al.,* 2010; Hall *et al.,* 2013). A substantial amount of scientific evidence indicates that the Caribbean is already experiencing the effects of a changing and variable regional climate regime (Gamble, 2009; Mimura *et al.,* 2007; Nurse *et al.,* 2014; Taylor *et al.,* 2011), typified largely by changes in mean surface temperature, seasonal shifts in rainfall and an increase in the incidence of extreme weather events in recent years (possibly associated with a warming trend across the Caribbean Basin). The vulnerability of Caribbean SIDS is accentuated due to their smaller geographic size, high concentration of settlements and resources along low-lying coastal strips, narrow natural resource base, poorly developed infrastructure, and limited human and economic resources.

The economic implications of a changing Caribbean climate are wide ranging and extremely complex in nature and scope. Increases in the intensity and/or frequency of extreme weather events such as droughts and hurricanes, escalating rainfall variability, higher surface temperatures and rising sea levels, combined with fragile ecosystems and the absence of effective climate-risk management practices and policies, all contribute to the Caribbean's overall vulnerability to climate change. In terms of the impact on different sectors, agriculture stands out due to the significant falls in crop production in recent years – most of which has been linked to a spate of extreme hydro-meteorological events and a host of diseases and pests, resulting in millions of dollars worth of damage to the sector. These climate-driven impacts on the Caribbean agriculture sector are likely to continue or worsen if urgent steps are not taken now to address the sector's underlying vulnerabilities. As it stands, the outlook for the sector is bleak as studies from other regions, including the Pacific, Latin America and Africa, have demonstrated that agriculture is particularly susceptible to the effects of climate change, with rural farming communities expected to be the most affected (Trotz and Lindo, 2013). The objective of this research report is to support the implementation of CTA's flagship project in the Caribbean by gathering information to develop capacity-building efforts for specific groups of farmers engaging in specific production activities in priority value chains so they may improve their access to key markets. Whereas a supply chain refers to the system and resources required to move a product or service from supplier to customer, the idea of a 'value' chain builds on this concept by considering the manner in which value is added throughout the lifecycle of a product. This involves the full range of activities that create and add value through the different phases of production, including the sourcing of raw materials and other inputs, processing, marketing, distribution, consumption and disposal. A range of value-chain actors are involved and interact with each other, including commodity producers, processors, distributors and consumers. Value is generally meant in a narrow economic sense but can also be interpreted to encompass non-monetary utility values, such as closing material loops, providing or preserving ecosystem services and adding customer value.

When applied to the agriculture sector, the value-chain approach offers a powerful lens through which to explore the wide range of factors affecting the ability of farmers and other industry actors to function effectively. An agricultural value chain basically refers to the whole range of goods and services necessary for an agricultural product to move from the farm to the final consumer. Strongly tied to this concept is the idea that actors are connected along a chain or through networks that are geared towards producing and delivering agricultural products to consumers through a sequence of activities. This includes 'vertical' chain activities (such as the sourcing of raw materials, production, harvest and post-harvest activities, processing, marketing and distribution) and 'horizontal' chain activities (such as finance provision, extension and other technical support, and the creation of an enabling environment). This report focuses on the threats climate change poses to the production of fruit and vegetables and roots and tubers in the Caribbean. These

two value chains are very important in terms of sustaining household food security and reducing poverty throughout the region, and provide an important source of income for thousands of smallholder and medium-scale farmers and their families. Any significant fall in the production of either fruit and vegetables or roots and tubers could therefore stem, if not reverse, past efforts in reducing poverty in the region.

The observed and projected effects of climate change on the region's agriculture sector are a major cause for concern for these two important value chains. This also has serious implications for the Caribbean in general, given recent efforts in developing sustainable agricultural-based value chains targeted at local and overseas markets and the region's continued dependence on the agriculture sector as a source of employment and income. While primary agriculture in the Caribbean contributes only an average of 10% to gross domestic product (GDP), this varies widely across the regional states, from 32% in Guyana to as low as 2% in Trinidad and Tobago (IICA, 2011). Even in countries where agriculture is not a major economic sector, subsistence agriculture is critical to the livelihoods of many rural poor households (Simpson *et al.,* 2009; Karagiannis *et al.,* 2012). Within the Caribbean Community (CARICOM), Haiti and Montserrat have the largest agricultural employment, with 60% and 33% respectively of their total economically active population working in agriculture (Simpson *et al.,* 2009, p. 156). Other countries, such as Belize, Jamaica, St Kitts and Nevis, Antigua and Barbuda, St Lucia, St Vincent and Grenadines, and Dominica, have agricultural employment rates higher than 20% of the total employed population.

The situation could be made worse as climate interacts with other stressors, such as changes in population and environmental degradation. Taking stock of these threats is crucial not only for the viability of the Caribbean agriculture sector, but also as a necessary first step towards the formulation and implementation of policies and programmes to effectively reduce poverty and achieve food security via the promotion of viable and climate-smart agribusiness enterprises.

The specific objectives of this research are to:

1. review available information to evaluate current and potential effects of climate change on fruit and vegetable and root and tuber value chains in the Caribbean;
2. identify the critical stages when the various actors (e.g., farmers, traders, processors) of the two value chains are most vulnerable to climate change and highlight how they are specifically affected;
3. Identify financing and other mechanisms (if any) that are available to value-chain actors to enable them to respond to the critical and vulnerable phases of these two prioritised value chains;
4. Identify the implications of the above for the development of targeted training and curriculum development, in particular, and scaling-up of climate-resilient solutions for fruit and vegetable and root and tuber value chains in general in the Caribbean.

Approach

This report is primarily informed by a detailed desktop review of available literature on current and potential climate-change effects on fruit and vegetable and root and tuber value chains in the Caribbean. The review was conducted between July and August 2016, and covered academic papers, technical reports and other data sources containing relevant sector-specific information on the two prioritised value chains.

Outline of the report

The report is divided into five main sections. First, it gives an overview of the economic impact of climate change on the two priority value chains in the Caribbean. This features climate-change trends and projections for the Caribbean and discusses some of the past and likely future effects on the agriculture sector due to these observed and predicted changes in climate. This is followed by information on policy environment in which agriculture value-chain actors in the Caribbean operate in and the financial mechanisms available to support climate-change adaptation and mitigation activities in the sector. This includes an inventory of existing and other potentially palliative financing mechanisms available to value-chain actors to respond to some of the critical gaps identified in the region. Then, the paper looks at some of the implications for scaling up climate-adaptation solutions in the two priority value chains across the Caribbean. Particular focus is given to the potential scope for technical cooperation, opportunities for climate financing, and current and future policy pathways. The report ends with a few concluding thoughts and key messages.

Economic impacts of climate change on priority agriculture value chains in the Caribbean

The Caribbean climate

There is a general consensus that the earth's climate is changing. In its last two major reports, The Intergovernmental Panel on Climate Change (IPCC, 2007, 2013) pointed to a progressively warmer global climate system linked to increasing global atmospheric concentrations of anthropogenic greenhouse gases (mainly carbon dioxide and methane) since the mid-eighteenth century. The global increases in carbon dioxide concentration are largely due to fossil fuel consumption and land-use change, while methane and nitrous oxide emissions are primarily the result of agricultural activities, such as livestock rearing. As these gases build up, they reabsorb heat reflected from the earth's surface, thereby trapping excess heat in our atmosphere (the greenhouse effect).

According to the IPCC, it is very likely that climate change is already having an impact on our planet and this is expected to worsen in the future. Studies indicate that the average global surface temperature has increased by approximately 0.6°C over the last century, and global climate models project an even greater increase over the course of the 21st century. In some cases, the temperatures may very well increase by 2–5°C by the end of the century, which would result in significant changes in the global climate system. Aside from resulting in more hot days and hot nights, numerous studies have pointed to a future characterised by rising sea levels, increased desertification, changing precipitation and weather patterns, and more frequent and intense climate extremes, such as droughts, tropical storms and hurricanes. Though these changes are likely to be global in scale, their cumulative effects seem set to affect the developing world more than developed countries.

The Caribbean, in particular, is expected to be among the regions most severely affected by global climate change. This is partly due to a range of regional characteristics, including the generally small geographic size of states; high concentration of settlements and economic activities along low-lying coastal areas; narrow natural resource base; and a heavy reliance on a limited number of climate-sensitive industries, such as tourism and agriculture. When superimposed on these existing conditions, climate change presents unprecedented challenges to regional development.

Considerable scientific evidence suggests that the Caribbean is already experiencing a changing climate (Tompkins *et al.,* 2005; Mimura *et al.,* 2007; Gamble *et al.,* 2010; Taylor *et al.,* 2011; IPCC, 2012, 2013; Nurse *et al.,* 2014). For instance, observational records for the Caribbean beginning in the late 1950s have shown that the number of very hot days (Tmax greater than or equal to 30°C) and very hot nights (Tmin greater than or equal 25°C) have been increasing throughout the region (Peterson *et al.,* 2002; Stephenson *et al.,* 2014). Studies have also shown that the Caribbean Sea has warmed by approximately 1.5°C over the last century and that sea-surface levels have risen in line with that of the global mean (1.8 mm yr^{-1}) since 1950 (Church *et al.,* 2004; Palanisamy *et al.,* 2012). Added to these trends is a moderate decline in precipitation across the northern Caribbean Basin coupled with evidence of greater seasonal and inter-annual rainfall variability, and more and increasingly prolonged dry spells especially during the summer period (Gamble, 2009).

Though there is a fair amount of uncertainty with model predictions (IPCC, 2013), within the climate science community there seems to be a general consensus that the regional climate will get progressively warmer and drier over the course of this century (Taylor *et al.* 2007; Stephenson *et al.* 2008; Gamble *et al.* 2010; Campbell *et al.* 2011; Taylor *et al.* 2012). In addition to these trends is a marked increase in hurricane and tropical storm activities in the region since the mid-1990s, which some believe may be linked more to a multi-decadal

oscillation in Atlantic sea-surface temperatures than to longer term climatic change (Pulwarty *et al.* 2010; Trotz and Lindo, 2013).

The impact of climate on the agriculture sector

We are likely to exceed a +2°C rise in global mean surface temperature by the end of this century if we continue on our current emissions trajectory (IPCC, 2014). In fact, some argue that even drastic reductions in global greenhouse gas emissions now will be insufficient to avoid some of the impending effects of climate change (Magnan, 2014). These changes are expected to result in a warmer, drier climate in the Caribbean, with greater inter-annual and inter-seasonal variations in traditional weather patterns.

Any significant fluctuation or change in the region's climate (especially in terms of temperature and rainfall) could have significant adverse effects on the agriculture sector, including a general reduction in productivity and increased risk of crop failure. Predicted water shortages and increases in evapotranspiration will present a direct problem for agricultural production. Studies have already shown, for instance, that increasing global temperatures in other regions over the last three decades have resulted in significant yield losses in many crops (Long and Ort, 2010; Lobell *et al.,* 2011). While this seems to be a likely scenario for the Caribbean, regional farmers are operating with only limited information on the likely impact of climate change and on the potential of available cultivars to withstand these changes.

Over the past decade, a lot of attention has been given to the potential impact that likely increases in the incidence and severity of extreme events could have on the Caribbean. Extreme weather events (possibly associated with a warming trend across the Caribbean Basin) have already had a considerable impact across the region, most significantly in terms of the increased occurrence of drought and the recent spate of hurricanes and tropical storms that have resulted in millions of dollars worth of damage to the region's productive sectors and infrastructure. The Caribbean's location in the Atlantic Basin potentially exposes the majority of regional states to hurricanes and their aftermath each year (Pielke *et al.,* 2003). Any increase in the frequency and magnitude of Atlantic hurricanes could therefore prove quite costly for the region as a whole.

A single hurricane can have a severe impact on an entire country. A case in point was the extensive damage Hurricane Ivan inflicted on Grenada in 2004. This hurricane alone damaged 90% of nutmeg trees across the island (displacing some 6,500 nutmeg farmers), destroyed 90% of the national housing stock (estimated at US$517 million or 38% of GDP) and 80% of total agricultural assets (estimated at 10% of GDP), with overall damages totalling US$824 million (Becken and Hay, 2007). In July 2005, almost one year after being struck by Hurricane Ivan, Grenada was hit yet again by another hurricane causing further damage to homes and other infrastructure on the island. In St Vincent and the Grenadines, records dating back to the early 1980s indicate that hurricanes and tropical storms have caused millions of dollars of damage. One sector that has continuously been affected is agriculture. In 2010, Hurricane Tomas resulted in an estimated damage of EC$67.2 million (US$24.87 million) in the agriculture sector alone, with approximately 98% of banana and plantain crops ruined (CDEMA, 2010).

In terms of drought, projections show a considerable drying trend for the majority of the Caribbean Basin, with estimates as high as a 30% reduction in rainfall by the end of this century (Neeling *et al.,* 2006; Campbell *et al.,* 2010; Hall *et al.,* 2013). This has serious implications for food and water security, and poses a clear and imminent threat to the viability of several important economic sectors throughout the region. Farming systems in the Caribbean are particularly exposed and vulnerable to climate-induced shocks and stresses given the agriculture sector's relatively high dependence on natural ecosystem services, being mainly rain-fed.

The cumulative consequences of these and future climatic changes can be catastrophic if urgent steps are not taken now to address underlying vulnerabilities. Toba (2009) estimated that the total annual impact of potential climate change on all CARICOM Member States and Associated Members by 2080 would be US$11.2 billion (referenced to 2007 US$). In addition, the report estimated the total impact on GDP (in 2007 US$) would be approximately US$99.3 billion or about 11.3% of the total annual GDP of all 20 CARICOM Member States and Associate Member States. Of these annual losses, US$3.8 million would be attributable to drought.

Given the region's development challenges, any reallocation of resources to address these and other climate-related issues is likely to hinder

efforts to address long-standing problems of poverty and social inequality in the Caribbean (Lloyd Evans *et al.*, 1998; Dodman *et al.*, 2009; Bishop and Payne, 2012). Furthermore, the burden of the disruption caused by climate change is expected to fall disproportionately on those who are already socially and geographically disadvantaged (Dow *et al.*, 2006; Mearns and Norton, 2010; Füssel, 2012). In the Caribbean, this is likely to include coastal populations, groups that depend on fragile ecosystems, and rural agricultural communities.

The impact of climate on roots and tubers and fruit and vegetables

Climate change is expected to have a significant negative impact on a wide range of economically important food crops throughout the Caribbean. The root and tuber and fruit and vegetable value chains are particularly susceptible given these sub-sectors' sensitivity and exposure to a range of climate-related hazards, as illustrated by the recent hurricanes, floods and droughts. In addition, the projected long-term changes in temperature and rainfall are likely to have a negative effect on regional agricultural production if measures are not put in place soon. In this section we take a closer look at the vulnerability of these two value chains to climatic changes, drawing on past records and on projections. Due to the dearth of information available for individual crops, we consider instead the experiences of individual countries within the Caribbean, namely Guyana, Jamaica and St Lucia.

Guyana is approximately 214,969 km², located in South America between Suriname and Venezuela, and bordering the North Atlantic Ocean, with a population of more than 700,000. It has a tropical climate and is characterised by a wet and a dry season. The Guyanese economy is heavily dependent on agriculture and mining, with key products being sugar, shrimp, timber, rice, gold and bauxite. Agriculture contributed some 34% of the GDP in 2010 and the sector has experienced moderate growth in recent years. The agricultural industry is dominated by sugar and rice.

Jamaica is located in the Greater Antilles and is south of Cuba and west of Haiti. It is the largest of the English-speaking islands in the Caribbean, covering a total land area of 11,000 km². The interior is very mountainous, with the Blue Mountain Peak rising to a height of 2,256 m. The average annual rainfall is 1,000 mm. Jamaica has a tropical climate characterised by two distinct rainy seasons separated by a dry season that is normally from June to August. Jamaica's economy depends heavily on services, which accounted for over 60% of GDP in 2015, and the country continues to derive most of its foreign exchange from tourism, remittances and bauxite/alumina. Agriculture contributed 6% to the GDP in 2015 and employs some 17% of the population. Leading agricultural commodities include sugar, bananas, coffee, cocoa, citrus, pimento, yams and a range of fruit and vegetables usually supplied to the domestic market and the local hotel industry.

St Lucia is part of the chain of islands that make up the Lesser Antilles. The island lies to the south of Martinique, north of St Vincent and north-west of Barbados. It covers a total land area of 616 km². The rainfall ranges from 1,524 to 3,505 mm per year. St Lucia's economy depends primarily on revenue from banana production and tourism with some input from small-scale manufacturing. The agriculture sector continues to play a major role in the economy, although its relative importance has declined in recent years due to the growing emphasis on the service sector. In 2009 agriculture contributed only 5% of the country's GDP; however, it accounts for a significant number of jobs – around one-fifth of the labour force. The banana industry is very important and other agricultural products of economic importance are cocoa, coconut, citrus fruit and livestock. The government has continued a programme to establish a new marketing and distribution system for non-banana agriculture, and has supported efforts to establish and promote tree crops such as mangoes and avocados. A variety of vegetables are produced for local consumption.

Extreme weather events

The Caribbean's geographic location in the Atlantic Basin exposes the entire region to the impact of hurricanes each year, though countries such as Trinidad and Tobago, Aruba, Bonaire, and Curacao are less likely to be hit by these weather systems because they are located further south (Pielke *et al.*, 2003). The impact of hurricanes alone on Caribbean countries in the past three decades has resulted in losses and damages estimated at US$5.7 billion. Of this, about 79% is estimated to be direct damage to infrastructure and capital assets, mostly within coastal towns and villages (Dellarue, 2012).

Hurricanes and tropical storms

Guyana. While Guyana is not located in the traditional North Atlantic hurricane belt, the country is affected indirectly by hurricane spiral bands as well as sea swells and tidal surges (CCCCC, 2009). These effects are likely to become more pronounced with any increase in hurricane frequency or intensity in the North Atlantic and Caribbean Sea. A few studies indicate a possible 10–20% increase in intensity of tropical cyclones under greater CO_2 conditions.

In addition, many tropical and extra-tropical weather systems influence Guyana's local weather, particularly the distribution and intensity of rainfall. Tropical waves, which normally occur during the hurricane season, can affect Guyana's coastal and inland areas, particularly west of the Demerara River. Tropical waves are responsible for the bulk of rainfall on Guyana's north-western coast and are often the cause of the extended first wet season.

The agriculture sector has been particularly affected by a series of intense rainfall events and floods in recent years. The 2005 and 2006 floods demonstrated how vulnerable Guyana's agriculture sector is to climate extremities, with the January/February 2005 floods causing an estimated US$55 million in damage to the sector, or 35% of the country's GDP for the year 2004. The bulk of the damage was incurred in the cash crops sub-sector, followed by sugar and rice (UNDP/ECLAC, 2005). The January 2006 floods caused total losses of US$22.5 million to the agriculture sector. About 1,118 farmers, covering an area of 27,583 acres, were affected. Losses in the rice industry amounted to an estimated G$1.9 billion (US$9.2 million), while the sugar industry incurred losses totalling G$24 million (US$115,824). In the 'other crops' category, the impact was estimated at G$1.7 billion (US$8.2 million) with some 5,107 acres of farmland affected, mainly bananas, plantains, root crops, legumes, vegetables and fruit (UNDP/ECLAC, 2006).

Jamaica. Hurricanes and tropical storms pose a severe threat to Jamaica's farming industry. A single hurricane can inflict millions of dollars worth of damage to the island's agriculture sector. In 1998, Hurricane Gilbert left US$4 billion in damage, 40% of which was in agriculture. Between 2000 and 2010, Jamaica was affected either directly or indirectly by as many as 14 hurricanes and 16 tropical storms (Mandal *et al.,* 2013), amounting to over J$23 billion (or roughly US$263 million) in damage and economic losses. These natural disasters not only decrease foreign-exchange earnings, but they also affect many livelihoods due to loss of employment in farming communities and in the agricultural and agro-processing sectors. The fruit and vegetables sub-sector has been particularly affected by instability and declining productivity. Table 1 presents the damages and losses in Jamaica's agriculture due to hurricanes and tropical storms since 2004.

As a result of hurricanes Charley and Ivan in 2004, 190,000 tonnes of sugarcane were lost and the entire banana sector was affected, causing US$1.4 million in damage. It took three months before agricultural produce was again available in the domestic market. Hurricanes Emily and Dennis in 2005 exacerbated this damage, while US$59,200 of damage was caused by Hurricane Dean in 2007. The total damage and losses to the agriculture sector resulting from Hurricane Sandy in 2012 was estimated at US$16.3 million (PIOJ, 2013). Banana farmers in the eastern parishes of St Mary, Portland and St Thomas were some of the hardest hit, with 93–100% of the crop across the three parishes destroyed. Damage to cash crops (banana/plantain, roots and tubers, vegetables, condiments) and fruit was estimated at US$14 million, affecting 37,000 farmers on 2,815 hectares of land. These hurricanes collectively caused damage to vegetables, fruit, ground provisions (root vegetables), bananas and plantains. In addition to crops, farm buildings and equipment, roads and irrigation equipment were significantly damaged.

The heavy showers generated from tropical depressions have had multiple impacts in almost all parishes throughout Jamaica. In September 2010, for instance, Tropical Storm Nicole generated over 500 mm of rainfall in just over five days (PIOJ, 2010). The total damage and losses to the agriculture sector in the storm's aftermath were estimated at US$6.5 million. In addition, damage to greenhouses was estimated at US$149,000 and damage to infrastructure, such as farm roads, was estimated at US$6.6 million.

St Lucia. The Windward Islands have been severely affected by several hurricanes in recent years, resulting in significant damage and losses in the agriculture sector. Grenada and St Lucia have been two of the hardest hit. In 2004 Hurricane Ivan damaged more than 14,000 homes in Grenada and destroyed one-third of the island's housing stock. The strong winds downed 80% of the nutmeg trees on the island, with other crop losses ranging from 60 to 90%. The total damage

Table 1: Damages and losses in Jamaica's agriculture from hurricanes and tropical storms, 2004–2010

Extreme events	Farmers affected	Crop area affected (ha)	Value of damage to crop (US$)	Value of damage to livestock (US$)
Hurricanes				
Charley – August 2004	986	792	2,962,524	61,092
Ivan – September 2004	117,698	11,130	81,332,882	22,650,593
Dennis – July 2005	6,700	610	3,588,144	838,215
Wilma – October 2005	19,973	1,572	5,582,099	1,142,032
Emily – August 2005	1,499	656	817,480	8,758
Dean – August 2007	63,707	5,473	18,857,473	1,094,074
Sandy – October 2012	37,000	2,815	15,400,000	950,000
Tropical storms				
Gustav – August 2008	24,255	2,777	8,771,256	450,370
Nicole – September 2010	18,601	3,741	6,084,138	370,966

Source: Rural Agricultural Development Authority (RADA)

inflicted on the island amounted to US$1.1 billion, representing about 200% of Grenada's GDP in 2004. Hurricane Ivan in 2004 caused moderate coastal damage to southern sections of St Lucia and downed several hundred banana trees, totalling US$2.6 million in damage. Three years later St Lucia was hit by another hurricane, this time causing major damage to the agriculture sector. In August 2007 Hurricane Dean swept across the island's 5,000 acres of banana farms in Mabouya Valley, Roseau Valley and Marc Marc, causing waterlogging or outright destruction of many of the plantations. An average of 75% of the banana crops were lost, bringing the total cost to the agriculture industry to US$13.2 million, or 0.5% of St Lucia's GDP.

In 2010 St Lucia was affected by another tropical cyclone, Hurricane Tomas. The excessive rainfall, flooding and high winds resulted in widespread damage to the country's housing stock and road infrastructure. The agriculture sector also suffered major losses, especially the banana industry, with the total damage to the sector, including forestry and fisheries, estimated at EC$151.74 million (US$56.2 million).

Droughts

Guyana. Guyana has suffered from acute drought in the past, primarily associated with the El Niño phase of the El Niño–Southern Oscillation climate cycle. The agriculture sector has been one of the hardest hit, with millions of dollars worth of damage and losses. One of the most severe droughts in Guyana's recent history began in late 1997 and extended into 1998, with accompanying forest fires. Between February and March 1998, rainfall fell to as low as 85–90% below normal in some areas. Drought conditions were so severe that water rationing was introduced throughout the country. In the agriculture sector, rice and sugar, the country's

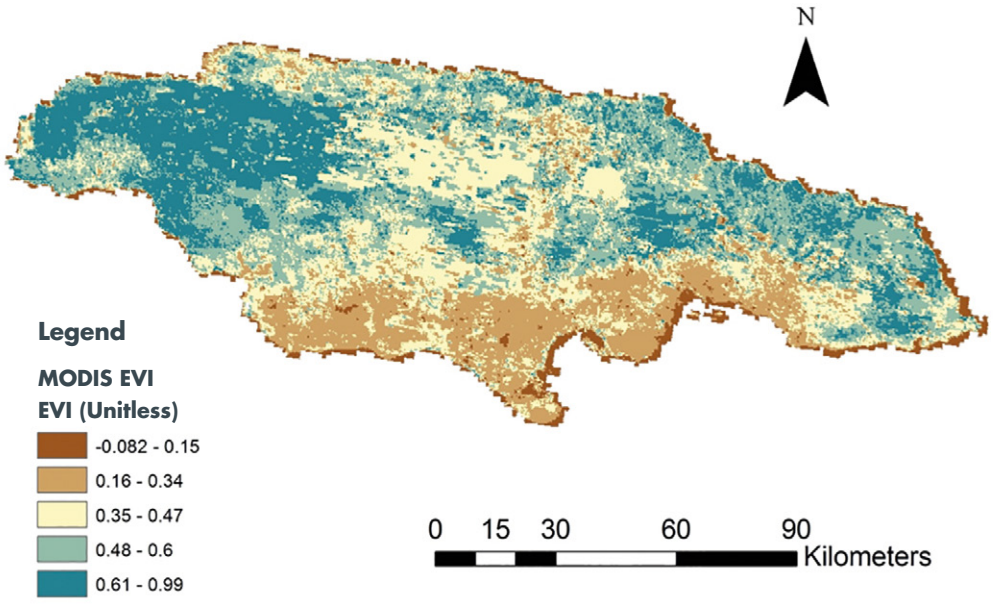
main export crops, were the most severely affected, with an estimated US$22 million lost in rice production and US$7 million in sugar. Losses of livestock and crops such as cassava, coconut and coffee were also significant.

Guyana has experienced several other drought events since then, one of the most severe in terms of intensity and economic impact beginning in 2009 and extending into early 2010, triggered by a particularly strong El Niño event. Drought-related impacts on the agriculture sector were quite extensive, resulting in significant water shortages and agricultural losses across the country.

Jamaica. Droughts are particularly damaging to Jamaica's agriculture sector because most farming systems across the island are open-field and rain-fed. Since Jamaica experiences a bi-modal rainfall pattern with distinct dry and rainy periods, hydro-meteorological disasters have a significant impact. Over the past two decades, the frequency and intensity of droughts have greatly increased. These hot, dry conditions create many challenges for farmers, especially across the southern belt where a significant portion of the nation's food is cultivated. Figure 1 shows the Normalized Difference Vegetation Index (NDVI) values for Jamaica for the month of August during the 2015 drought.

A few studies have demonstrated the wide-ranging impact that a progressively drier and warmer regional climate could have on Jamaica's agriculture sector, including a reduction in plant-available moisture due to increased rates of evapotranspiration, increased spread of some pests and diseases, and a decline in certain crop yields[1] (Eitzinger *et al.*, 2009; McGregor *et al.*, 2009). This poses a serious threat to the viability of the sector. Drought conditions have been particularly damaging in southern parishes, including the breadbasket region of Manchester and St Elizabeth. These two parishes alone account for approximately 40% of the island's domestic agriculture production, the vast majority of which consists of fruit and vegetables. Neighbouring parishes, such as Clarendon, St Catherine and St Thomas, which are also significant producers of domestic food crops, have also been affected.

Figure 1: Normalized Difference Vegetation Index values for Jamaica, 13–28 August 2015



Note: Lower values (brownness) represent relatively dry conditions and plant stress, while higher values indicate greater vigour and photosynthetic capacity (or greenness).
Source: Supplied by Sarah Buckland (UWI) and Ted Allen (IRI)

[1] Information from the Meteorological Service of Jamaica (metservice.gov.jm) indicates that for the months of June and July 2014, the island recorded rainfall levels of 33% and 37% of the 30-year mean respectively.

Table 2 shows the cost of and number of farmers affected by drought in selected years from 1995 to 2008. Between 2010 and 2015, Jamaica experienced drought conditions every year with the exception of 2011. Drought conditions in the second half of the 2014 calendar year led to a 17.7% decline in agriculture output (PIOJ, 2014). The drought conditions curtailed planting activities and lowered crop yields. While these trends do not constitute long-term climate change by any means, they certainly illustrate how susceptible the island's agriculture sector is to these and other extreme hydro-meteorological hazards. Tubers such as Irish potatoes and yams are particularly sensitive to changes in temperature and precipitation (moisture), and are therefore expected to come under increasing stress with projected increases in temperature and incidence of drought across the northern Caribbean Basin.

St Lucia. While impact data on Saint Lucia is limited, our desktop review indicated that the country has been severely affected by several intense drought events in recent years. The 2009/2010 drought resulted in severe water shortages across the island, leading to reduced domestic crop production and major spikes in local food prices.

Long-term agro-ecological impacts

Only a few studies conducted in the Caribbean have looked at the long-term implications of climate change on agriculture and they are primarily based on crop-climate suitability models, such as ECOCROP, MaxEnt and DSSAT. The majority of these models have been developed and employed outside the Caribbean and are not necessarily applicable to the region, given the small geographic size of most regional states and the narrow range of crops.

A review of these studies indicated that the expected long-term changes in temperature and rainfall patterns across the Caribbean Basin may result in considerable losses in regional crop production due to a reduction in suitable growing areas.

Table 2: Damages and losses in Jamaica's agriculture from droughts, 1995–2008

Year	Farmers affected	Crop area (ha)	Crop value (US$)	Livestock value (US$)
1995	–	1,817	14,755,157	–
1997	–	5,907	25,061,461	–
1999/2000	8,278	2,779	16,981,276	–
2005	14,269	2,058	8,384,082	–
2008	70	79	575,513	10,795

Source: Rural Agricultural Development Authority (RADA)

Case study on Jamaica

Results from crop-climate suitability studies conducted in Jamaica by the International Centre for Tropical Agriculture (CIAT) in collaboration with the University of the West Indies (UWI) indicate there will be a general decline by 2050 in the agro-ecological conditions required to cultivate a number of economically significant crop species that are commonly grown in Jamaica. The island is projected to experience a geographical shift in the ecological niche of most crops to higher altitudes as mean temperature increases, resulting in fewer available areas for open-field cultivation by 2050. This will have severe implications for greenhouse cultivation as well. In the case of a mean annual increase in temperature, crops grown in greenhouses in low elevations could suffer from heat stress if the houses are not properly ventilated.

Table 3 summarises the results from the study and indicates that the most affected crops, in terms of the projected reduction in suitable growing conditions, will be cabbage, carrot, ginger, sweet potato (high altitude) and tomato (high altitude), with declining climate suitability ranging from 25 to 47%. By 2050, suitability is predicted to decline for a number of crops, including cabbage, carrot and ginger. Crops with average suitability values below 40% (e.g., ginger) will require major intervention to sustain productivity.

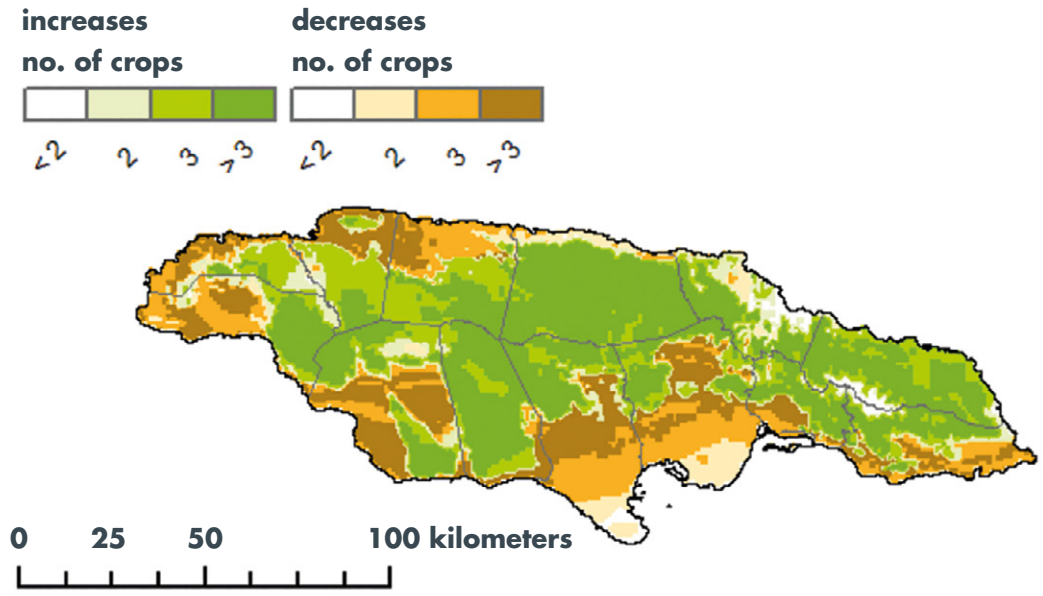
A recent assessment of five crops commonly grown in Jamaica using the Representative Concentration Pathway (RCP) 8.5 scenario shows that, in general, decreased climate suitability coincides with the driest areas of the island (annual rainfall <1,500mm): the north-western coast and a large part of the southern parishes of Clarendon, St Catherine and St Elizabeth. In contrast, positive suitability gains will more likely take place in higher altitudes that are characterised by cooler and wetter micro-climate regimes (see Figure 2). The crops selected were yams, bananas, sweet potato, cassava and ginger.

Table 3: Average suitability change for selected crops by 2030 and 2050

Crop	Average current suitability	Average suitability for 2030	Average suitability for 2050	Average suitability change by 2030	Average suitability change by 2050
Banana	69	82	87	13	18
Cabbage	91	73	57	–19	–35
Carrot	88	66	53	–22	–35
Cucumber	74	86	93	13	19
Ginger	81	53	34	–27	–47
Irish potato	82	69	59	–13	–22
Lettuce	92	76	64	–16	–28
Mango	63	69	62	7	–1
Orange	59	61	53	2	–5
Sweet potato (low altitude)	70	85	92	15	22
Sweet potato (high altitude)	91	72	56	–19	–36
Tomato (low altitude)	68	84	91	16	23
Tomato (high altitude)	88	74	64	–14	–25
Zucchini	77	90	95	13	18
All crops	**78**	**74**	**69**	**–4**	**–9**

Note: Sweet potato is calculated for two different altitude levels (low: mostly red skin, with white flesh; high: mostly red skin, with yellow flesh).
Source: CIAT-OXFAM, 2011

Figure 2: Spatially modelled future suitability of studied crops in Jamaica



Source: Eitzinger *et al.*, 2015

When the crop suitability changes were compared across altitudinal ranges and land cover, the results indicated that climate change may represent negative impacts for a number of crops grown in Jamaica, especially in areas between 0 and 500 m above sea level. The tendency for higher elevations to gain suitability in the future could increase the risk of forested areas being converted into farmlands. These areas are also characterised by hilly and rugged terrain and are prone to landslides and soil erosion, especially if vegetation is removed on a large scale. Increases in mean temperature could also result in greater incidence of plant pests and diseases. Any significant increase in pest and disease infestation will have serious implications for the livelihood security of many Jamaican farmers.

Note that these predictions have serious implications for farming activities in both the domestic and export crop sub-sectors. The indications from observed and modelled climate variables for Jamaica is that medium- and long-term changes in climate could adversely affect water resource availability and crop performance if appropriate adaptation measures are not put in place soon. While Jamaica has considerable surface and groundwater resources, local water demand is met mainly from groundwater sources. Seawater intrusion into coastal aquifers and the over-abstraction of existing wells already pose a management challenge (Simpson *et al.*, 2012). The situation is made worse for the rain-fed agriculture sector. The fact that the agriculture sector accounts for between 75 and 85% of the water consumed in the country on an annual basis clearly shows how sensitive the sector is to these anticipated changes in rainfall and temperature. Declining and variable rainfall patterns coupled with higher temperatures will most certainly lead to increased water stress in both plants and livestock.

The relative impact of climate change on the different value-chain actors

While climate change is expected to inflict widespread damage on the region's agriculture sector, the impacts are not expected to be uniform. Changes to the region's climate will certainly affect some crops and value-chain actors more than others. Fruit and vegetables and roots and tubers will come under increasing stress as the region's climate gets progressively warmer and drier. In addition, extreme climate events such as hurricanes and droughts are expected to become more frequent and intense, with potentially severe consequences for certain value-chain actors in the agriculture sector. The

remainder of this section outlines the nature and extent of their vulnerability to climate change for some of the key value-chain actors.

Farmers

Farmers in the Caribbean are particularly vulnerable to climate-related impacts given the nature of their farming systems and the socio-economic landscape in which they operate. The majority of farmers in the Caribbean operate on farm plots less than 1 acre in size and cropping systems are normally labour intensive and rain-fed. Many of these farmers also operate with limited access to extension support services and financial assistance. As the climate becomes less predictable, these vulnerabilities are going to become more pronounced.

Small-scale farmers are particularly disadvantaged due to their limited access to critical livelihood assets and inputs. A few studies have demonstrated the disproportionate effects of a progressively drier and warmer Caribbean climate on regional farmers. In their case study of southern St Elizabeth (considered to be the breadbasket parish of Jamaica), McGregor *et al.* (2009) documented the impact of two consecutive years of multiple hazard events on small-scale farming systems. Between 2004 and 2005, the region experienced two major drought events (one of which lasted for seven months, starting in late 2004 and extending into 2005), four hurricanes (Charley and Ivan in 2004 and Dennis and Emily in 2005), Tropical Storm Wilma (late 2005), and a series of bush fires causing serious and widespread damage to crops throughout the area. The study revealed that, cumulatively, small-scale farmers were disproportionately affected over the period, primarily due to their relatively limited access to critical farm inputs such as seeds, guinea grass (used for mulch) and water. During the drought, this vulnerability was compounded by inefficiencies in government-led relief efforts, in the form of a poorly orchestrated water trucking programme, and the prohibitive cost of accessing water from the informal water trucking operations that emerged shortly after. More importantly, the study hinted at the uneven and polarising effects that exposure to these multiple hazards may have had within the individual farming communities due to pre-existing vulnerabilities and socio-economic inequalities, especially among small, resource-poor farmers.

Female farmers are especially vulnerable to climate-change impacts given their additional responsibilities at home. Most women have to balance traditional household chores and duties along with farming activities. Women also often do not have the same level of access to land and other resources as do their male counterparts, placing them in a precarious position.

It is instructive to note here that some of the main factors driving the vulnerability of these farmers to climatic shocks are systemic. Any effort at offsetting climatic stressors will therefore have to address inherent weaknesses and inefficiencies in the sector, including the relatively short-term planning cycles practised by some farmers, the inadequate resources available to support implementation of actions, absence of suitable and cost-effective technologies and innovations, and the limited involvement of the private sector in the industry. Non-climate shocks and stresses, such as praedial larceny (the theft of agricultural produce or livestock from a farm or estate) and insecure land tenure, can also detract from long-term investment and innovation.

Traders and distributors

Traders of agricultural commodities are vulnerable to both short-term climatic shocks and longer term climatic stresses. Hurricanes and tropical storms usually result in shortages in local food supplies, which negatively affect traders' ability to meet their clients' demand directly after a storm. This problem is usually compounded by either an absence of or limited storage facilities. Most agricultural traders in the Caribbean do not possess cold-storage facilities and are generally unable to store fresh agricultural produce for extended periods. Instead, locally grown crops are generally sourced from nearby farming communities a few days before they are transported to the market. Furthermore, floods generated by tropical storms and intense rainfall events may destroy farm roads and make some communities inaccessible.

Other extreme events, such as drought and bush fires, pose a severe threat to the operation of agricultural traders, particularly in terms of satisfying market demand on a consistent basis. Droughts can be very damaging to local crops, particularly fruit and vegetables. During a severe drought, traders generally have to resort to food imports or apply a significant mark-up on their sale prices to remain viable. In some instances, especially in the case of binding long-term contracts, traders are more or less forced to honour their contract prices. Again, the lack

of or limited storage capacity typical of most traders in the Caribbean reduces their ability to manage supplies, especially during times of glut.

While most traders can resort to food imports during shortages, with the anticipated increase in the frequency and severity of extreme weather events in the future, there is some concern that relying on food imports may not always be a viable option. Hurricanes, for instance, can cause huge delays in the shipment of food and other commodities.

Agro-processors

Agro-processing companies are similarly affected by food shortages caused by extreme weather events, which have severely hampered the operations of local agro-processing companies across the Caribbean in recent years. These disruptions in operation mean that machinery is under-utilised, resulting in a higher fixed cost of operation per unit of raw materials processed. Hurricanes and droughts are especially damaging and have caused millions of dollars worth of losses in critical farming infrastructure as well as crops.

Unlike agricultural traders, however, agro-processors are less sensitive to minor fluctuations in food prices and food quality. This is due to agro-processing companies normally demanding agricultural products that are grade C and below, and are therefore sold at relatively low prices. In some instances, agro-processing companies could even benefit from certain climate-related shocks (e.g., droughts) as local crop quality declines and farmers get squeezed out of other markets.

In instances of severe drought, water shortages could have a negative impact on agro-processing operations. Water is an important input for agro-processors in terms of both the production of their products and their ability to adhere to national and international food safety standards.

Higher temperatures could result in higher energy costs for some agro-processors. This could increase production costs significantly, potentially threatening the viability of small agro-processors that are more sensitive to changes in their operational expenditure.

Input suppliers

Suppliers of farm inputs (e.g., seeds, fertilisers, farm tools) are also susceptible to extreme weather events. Farm stores can get damaged and imported supplies may be delayed over an extended period, for instance. At the same time, farm stores can also benefit from natural disasters, through the provision of seeds and other planting material to farmers for replanting.

Critical stages when value-chain actors are most vulnerable

Climate-related impacts are felt differently among different actors throughout the value chain. In this sub-section we outline some of the critical stages in agriculture value chains in the Caribbean when value-chain actors are most vulnerable to climate change.

Production

One stage where value-chain actors are most vulnerable to climatic shocks is the production phase. Since the majority of farmers in the Caribbean rely on open-field cultivation, they are more sensitive to weather extremes and variable climate. Lack of irrigation, limited access to agricultural extension support and the general absence of climate information and services targeted at the agriculture sector make it particularly difficult for regional farmers to effectively prepare for these climatic shocks. Most of the impact from the recent spate of droughts across the region, for instance, has been felt at the farm level due to losses in crops and the high costs of trucking water to farms. Damage to crops and farm infrastructure, such as greenhouses or water tanks, from events such as hurricanes and tropical storms can result in loss of income and the displacement of already marginalised livelihoods.

As the climate becomes less predictable, it will become increasingly difficult for farmers to effectively manage their farms, including knowing when to purchase and apply inputs such as fertilisers to crops. This problem is even more acute among small, resource-poor farmers who have very limited capital at their disposal and who often lack collateral security. As such, they are less likely to have additional funds set aside in the event of a disaster or an emergency. The same problem exists with regards to pests and diseases. As the region's climate gets progressively warmer, we could see an increase in outbreaks of new and existing pests and diseases. The ability of many regional farmers to manage these outbreaks could be constrained by limited access to funding resources and technical support.

Post-harvesting

Another critical stage in the value chain where actors are vulnerable to climatic threats is post-harvesting. Hurricanes and torrential floods can cause severe damage to post-harvest infrastructure and result in loss of goods. Loss of electricity could lead to spoilage and a general fall in product quality. Blocked roads and damage to vehicles used to transport agricultural products to markets could result in significant delays in product delivery as well as losses due to spoilage. Gradual increases in temperature will also pose a strain on food storage as warmer conditions increase the risk of spoilage. The setting-up of cold-storage facilities will therefore become extremely critical in post-harvest management as the region's climate gets progressively warmer, which presents a major challenge for the majority of Caribbean farmers who, on their own, are not able to invest in such infrastructure.

Agro-processing and distribution

Other stages where value-chain actors are vulnerable are agro-processing and market distribution/retailing. In the case of the former, loss of electricity and water shortages could significantly hamper agro-processing operations across the region, as would damage to plant infrastructure. Damage to roads and interruptions in shipping services caused by hurricanes and floods may result in delays sourcing agricultural products and other inputs, thereby reducing profitability and increasing market losses. The marketing and distribution of agro-food products is also susceptible to climatic impacts; shortages in local crops may increase farm-gate prices significantly, which in turn will increase the operational costs of agri-marketing and retail firms and traders.

Financing and extension services

Climate change will also affect horizontal chain activities, such as agricultural financing and the provision of agricultural extension services. Banks and other credit lending institutions are affected by climatic shocks because any risks or losses faced by their clientele (including farmers and other value-chain actors) are usually passed on to them. These risks include clients' reduced profitability; increased withdrawals from existing savings accounts; and delayed loan repayments and high default rates due to loss of income or loss of assets. In many cases, banks and other credit institutions are often forced to reschedule loan repayment periods in order to remain viable.

Policy and financial support to agriculture value-chain actors against the impacts of climate change

This section outlines some of the recent progress made in the Caribbean to provide policy and financial support to agriculture value-chain actors in response to the threats posed by climate change. The following subsection provides an overview of the policy environment shaping climate-change discourse and action (referring here to both adaptation and mitigation measures) at the global, regional and national scales. The next subsection describes several major financing mechanisms available to agriculture value-chain actors in the region. This is followed by a selection of case studies showcasing adaptation and resilience-building in the regional agriculture sector. The section ends with a brief discussion of possible adaptation options, taking note of the major gaps and areas that require urgent and strategic action for the Caribbean agriculture sector.

The policy environment

Global context

A number of global initiatives have had a significant bearing on climate-change discourse and strategies in the Caribbean, key among which is the United Nations Framework Convention on Climate Change (UNFCCC). A primary objective of the UNFCCC is to stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system, in line with international treaties and protocols. The Kyoto Protocol is an international treaty linked to the UNFCCC that commits its parties to globally binding emission reduction targets. The Protocol, like the Convention, is designed to assist countries in adapting to the adverse effects of climate change through the development and deployment of technologies that can help increase resilience. The Adaptation Fund was established to finance adaptation projects and programmes in developing countries that are parties to the Kyoto Protocol.

One of the defining features of the UNFCCC is the requirement for signatory nations to establish national inventories of greenhouse gas emissions and removals. Most CARICOM Member States have ratified the Convention and are thus required to report periodically on their inventories and efforts geared towards removing greenhouse gases not controlled by the Montreal Protocol[2] as well as outline all major activities undertaken in their countries to implement the Convention. Almost all CARICOM Member States have submitted their First National Communication to the UNFCCC Conference of the Parties, with some countries, including Jamaica, Trinidad and Tobago, and Belize, submitting their Second National Communication (MSJ, 2011; NMS, 2000). Jamaica is preparing its Third National Communication and first Biennial Update report.

Another international initiative worth mentioning is the Intended Nationally Determined Contributions (INDCs) submitted by Caribbean states as part of the COP21 proceedings. INDCs are individual (country level) and voluntary commitments for post-2020 climate action. These documents signal a country's priorities, goals and intentions in relation to achieving a low-carbon, climate-resilient future. For the Caribbean, agriculture features prominently in the INDC submissions, in terms of regional states' mitigation and adaptation goals; promoting low-carbon, sustainable, climate-resilient agricultural production and enhancing regional food security are top concerns. Several regional governments have highlighted the vulnerability

[2] The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion.

of the agriculture sector to negative climate-change impacts, while stressing the importance of prioritising resilience-building in the sector to ensure food security and the achievement of other development goals. A combination of policy, research, incentives and capacity-building at the local, national and regional levels have been identified as necessary to transform Caribbean agriculture into a low-emission, climate-resilient sector. However, the achievement of these goals and actions is highly contingent on regional states receiving adequate levels of external support, including financial assistance, investment, technology development and transfer, and capacity building.

Regional context

Concerns about climate change have been on the Caribbean policy agenda for just over two decades. One of the early catalysing events was the United Nations Global Conference on the Sustainable Development of Small Island Developing States, which took place in Barbados in 1994. Emerging from the conference was the Barbados Programme of Action, a 14-point programme that laid out a number of specific sustainable development challenges faced by small island developing states, including climate change and sea-level rise. These concerns eventually led to the adoption of a series of large-scale, basin-wide initiatives in the Caribbean aimed at enhancing the region's ability to cope with climate change. These initiatives have shaped the regional discourse about how to measure and respond to climate change and its impacts, and have also funnelled significant resources towards particular sectors, such as agriculture, in many Caribbean countries.

The establishment of the Caribbean Community Climate Change Centre in August 2005 represents another major regional milestone. The CCCCC coordinates the region's response to climate change, working on effective solutions and projects to combat the environmental impacts of climate change and global warming. It provides climate change-related policy advice and guidelines to the Caribbean Community Member States through the CARICOM Secretariat and to the UK Caribbean Overseas Territories, and is the archive and clearing house for regional climate-change data and documentation. The Centre has been accredited as a regional implementing entity by the Board of the Green Climate Fund. Other relevant regional agencies are the Caribbean Development Bank, Caribbean Agricultural Research and Development Institute (CARDI), the University of the West Indies and the Caribbean Institute for Meteorology & Hydrology (CIMH), along with regional and international development partner agencies and civil society organisations.

An array of past and ongoing regional policies and programmes have direct linkages with agriculture and will be influential in facilitating the sector's capacity to mitigate and adapt to climate change. The CCCCC is guided by the CARICOM Regional Framework for Achieving Development Resilient to Climate Change and its accompanying Implementation Plan. This framework provides a roadmap for achieving climate-compatible development in the Caribbean over the period 2009–2015, focusing on identifying and consolidating complementary activities that utilise the CCCCC's and other regional organisations' capacity and experience in addressing adaptation to climate change. The framework comprises four strategies and associated goals to significantly increase the resilience of CARICOM economies:

1. mainstreaming climate-change adaptation strategies into the sustainable development agendas of CARICOM states;
2. promoting actions to reduce greenhouse gas emissions through energy efficiency, conservation, and switching to renewable energy sources;
3. encouraging action to reduce the vulnerability of environmental and human systems in CARICOM countries to the impacts of a changing climate;
4. promoting action to derive social, economic and environmental benefits through the prudent management of standing forests in CARICOM countries.

Some of the main policies and programmes that have been implemented within the past two decades are outlined in Table 4.

National context

Over the past two decades, Caribbean states have implemented a range of national programmes and participated in a number of regional projects (including those listed in Table 4) designed to build national, institutional and individual capacities. The formation of National Designated Authorities provides a critical and strategic link between individual CARICOM Member States, the CCCCC and the Global Climate Fund. The CCCCC works through NDAs to set priorities for climate-resilient development at the regional and country levels.

Table 4: Past and current policy initiatives in the Caribbean

Programme	Period	Description
Caribbean Planning for Adaptation to Climate Change (CPACC)	1998–2001	This was a Global Environmental Facility (GEF) Stage 1 project implemented by the World Bank and executed by the Organization of American States. The CPACC was a direct response to the mandates set out in the SIDS/BPoA and was aimed at boosting national-level capacities to prepare and cope with the adverse effects of global climate change, particularly sea-level rise, in coastal and marine areas, through vulnerability assessment, adaptation planning and other related capacity-building initiatives. The project also involved the design of a Regional Sea Level/Climate Monitoring Network, and regional database and information systems to help regional and national institutions acquire, analyse, store and disseminate data. The GEF provided US$6.5 million in funding.
Adaptation to Climate Change in the Caribbean (ACCC)	2001–2004	This programme sought to build climate-change adaptation into existing planning mechanisms, enhance scientific and technical competence within the region, and increase knowledge and information on climate change. It was also aimed at enhancing regional states' involvement in international climate negotiations. Built on the foundation laid by CPACC, including addressing some of the gaps identified during implementation of CPACC, this project also facilitated the establishment of the Caribbean Community Climate Change Centre founded in Belmopan, Belize. The initiative was funded by the Canadian International Development Agency to US$3.5 million.
Mainstreaming Adaptation to Climate Change (MACC)	2003–2009	This programme was developed to facilitate an enabling environment for climate-change adaptation through building capacity to assess and reduce vulnerability to climate-change risks and support public education and outreach initiatives pertaining to climate change. Other activities were developing national policy frameworks to guide adaptation action within participating member states; preparing national pilot adaptation projects and mainstreaming climate-change issues into key sectoral activities. GEF funded the project to the sum of US$11 million.
Special Program on Adaptation to Climate Change	2006–2011	This initiative launched several adaptation projects in and around the coastal zone areas of Dominica, St Lucia, and St Vincent and the Grenadines, including rainwater harvesting, desalination, improved building codes and training aimed at improving the management of national parks and other forest-based resources. The programme was funded by GEF and the World Bank to US$2.1 million.
Regional Framework for Achieving Development Resilient to Climate Change	2009–2015	The framework was geared towards mainstreaming climate-change adaptation strategies in new and existing regional and national development plans; promoting actions to reduce greenhouse gas emissions; reducing the vulnerability of environmental and human systems in the Caribbean to climate change; and promoting prudent management of standing forests.

Pilot Program for Climate Resilience (PPCR)	2008–present	The PPCR has initiated ongoing efforts in 18 countries, including six Caribbean nations (Dominica, Grenada, Haiti, Jamaica, St Lucia, and St Vincent and the Grenadines) as well as region-wide initiatives in the Caribbean and Pacific Islands. The programme is funded by the Climate Investment Fund to US$11 million.
Strategic Program for Climate Resilience (SPCR)	2012–present	This programme is aimed at improving capacities for data collection and analysis, monitoring and climate modelling, and is funded by the Climate Investment Fund to US$10.6 million. This is in addition to US$69 million available to the six participating countries in the programme.

Other country-level activities include the development of national climate-change strategies and action plans and the mainstreaming of climate-change concerns in sector policies and plans. There has also been a lot of work done on building public education and awareness about climate change at the national level.

Despite the participation of CARICOM Member States in the UNFCCC and Kyoto Protocol, asymmetries still exist between countries in terms of national, institutional and individual capacities. One of the biggest challenges is the absence of accurate and up-to-date data on climate-related impacts and sector-specific vulnerabilities.

Financing mechanisms available

A number of funding sources are available for climate change-related activities for value-chain actors in the Caribbean agriculture sector. A fair few of these funds are available through multilateral financing mechanisms. These include:

- *The Adaptation Fund*: This is a financial instrument under the UNFCCC and has been established to finance concrete adaptation projects and programmes in developing country parties to the Kyoto Protocol, in an effort to reduce the adverse effects of climate change. The Fund is financed by a 2% share of the proceeds from the Clean Development Mechanism (CDM).
- *Green Climate Fund (GCF)*: The GCF was adopted as a financial mechanism of the UNFCCC at the end of 2011 and is designed to attain the mitigation and adaptation goals of the international community. Over time it is expected to become the main multilateral financing mechanism to support climate action in developing countries. Since becoming accredited, the CCCCC has been the direct interface and conduit for GCF funding for CARICOM Member States. Funding proposals are submitted through NDAs and then vetted and passed on to the CCCCC.
- *Clean Technology Fund (CTF):* This is one of two multi-donor trust funds within the Climate Investment Funds. It promotes scaled-up financing for demonstration, deployment and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emission savings. Channelled through the African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, Inter-American Development Bank and World Bank Group, the CTF finances 12 country programmes and one regional programme. At the moment, only Haiti among the countries relevant to CTA's project has benefited from the CTF, with assistance amounting to approximately US$16 million.
- *Global Environment Facility (GEF) Trust Fund:* This supports the implementation of multilateral environmental agreements and serves as a financial mechanism of the UNFCCC. It is the longest standing dedicated public climate-change fund. Climate change is one of the six focal areas supported by the GEF Trust Fund. The GEF administers several funds established under the UNFCCC, including the Least Developed Countries Trust Fund and the Special Climate Change Fund.
- *Special Climate Change Fund (SCCF):* This fund was created in 2001 to address the specific needs of developing countries under the UNFCCC. It covers the incremental costs of interventions to address climate change relative to a development baseline. Adaptation to climate change is the top priority of the SCCF, although it can also support technology

transfer and associated capacity-building activities. The SCCF is intended to catalyse and leverage additional finance from bilateral and multilateral sources, and is administered by the Global Environment Facility.

- *Global Climate Change Alliance (GCCA):* This is an initiative of the European Union. Its overall objective is to build a new alliance on climate change between the European Union and the poor developing countries that are most affected and which have the least capacity to deal with climate change. The GCCA does not intend to set up a new fund or governance structure but is working through the European Commission's established channels for political dialogue and cooperation at national and international levels.
- *Forest Carbon Partnership Facility (FCPF):* This is a World Bank programme and consists of a Readiness Fund and a Carbon Fund. The FCPF was created to assist developing countries to reduce emissions from deforestation and forest degradation, enhance and conserve forest carbon stocks, and sustainably manage forests (under the REDD+ agenda, described in more detail below).
- *Pilot Program for Climate Resilience (PPCR):* This is a targeted programme of the Strategic Climate Fund, which is one of two funds within the Climate Investment Fund's framework. The PPCR aims to pilot and demonstrate ways in which climate risk and resilience may be integrated into core development planning and implementation by providing incentives for scaled-up action and initiating transformational change, particularly in developing countries and regions with a demonstrable vulnerability to the adverse effects of climate change.
- *UN-REDD Program:* This fund was established and is coordinated by the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and the United Nations Food and Agriculture Organization (FAO). This multi-donor trust fund allows donors to pool resources and provide funding with the aim of significantly reducing global emissions from deforestation and forest degradation in developing countries. The UN-REDD Program supports the capacity of national governments to prepare and implement national REDD strategies with the involvement of all stakeholders.

Through the principle of 'common but differentiated responsibilities', the UNFCCC commits the developed country parties of the Convention to assist developing countries pay for climate-change adaptation and mitigation activities, which is estimated by the World Bank to be around US$40 billion per year (World Bank, 2008). While the funds are technically adequate to achieve climate-resilient development, the sums of money flowing through these instruments need to be substantially increased. Many developing countries have found it challenging to meet the requirements to apply for funding under these mechanisms, however. With key institutions like the CCCCC and the Caribbean Development Bank gaining accreditation with the Green Climate Fund, the region is now in a better position to increase its share of available climate financing. Utilising climate finance requires strong regional and national institutions capable of effectively deploying money and overseeing the implementation of high-impact initiatives.

There is a need to tap into other financial resources. The forging of bilateral agreements could provide useful assistance where possible and there are several bilateral funds that regional states could tap into. One example is the International Climate Fund (ICF), which is the primary channel of UK climate-change finance. It became operational in 2011, as an outcome of the Spending Review 2010, and replaced the Environmental Transformation Fund. The ICF is designed to help developing countries adapt to climate change, embark on low-carbon growth and tackle problems such as deforestation. Other examples are Germany's International Climate Initiative (ICI)[3] and Norway's International Climate and Forest Initiative (ICFI)[4], both of which support the development of the REDD+ international agenda, which seeks to reduce emissions from deforestation and forest degradation through either the preservation or sustainable use of forest resources.

There are also a lot of opportunities for private-sector financing, which include contributions from the regional business community and philanthropic organisations, such as the Clinton Foundation.

[3] The Dominican Republic is a beneficiary of the ICI.
[4] Guyana is a beneficiary of the ICFI (so far receiving approximately US$66 million in funding).

Adaptation case studies

A growing number of adaptation projects in the Caribbean are targeted at the agriculture sector. The majority of these are demonstration projects and are usually limited to a few communities or pilot sites. Some of the main areas of focus are:

- building resilience through the transfer of new technologies, such as irrigation facilities (including rain harvesting and catchment ponds), and protected forms of agriculture;
- identifying and promoting the use of more resistant crop varieties;
- preserving or enhancing planting material through the development and expansion of regional gene banks and tissue culture facilities;
- providing training aimed at improving land husbandry techniques, including the management of national parks and other forest-based resources;
- developing risk insurance/transfer schemes for climate-related disasters;
- transferring new climate-smart farming techniques using innovative and participatory forums, such as farmer field schools;
- improving the flow of relevant weather/climate information and services to local farmers, including climate monitoring and weather forecasting, data retrieval and the use of geospatial tools to map and monitor disaster risks.

Table 5 summarises examples of adaptation and resilience-building initiatives in the Caribbean.

Table 5: Examples of adaptation and resilience-building projects in the Caribbean

Focus	Country/ area	Description of project
Technology transfer through the provision of irrigation systems and protected agriculture	Dominica, Milton	The Milton Irrigation & Protected Agricultural Pilot Project is aimed at informing and encouraging adaptation measures to changing climatic conditions among farmers in Dominica through the implementation of an irrigation system. The irrigation scheme is intended to serve 20 ha of agricultural land in the Milton area which presently receives 100% of its crop water requirement from rainfall. The irrigation system consists of: (i) a concretised dam at one of the tributaries of the Dublanc River at an elevation of 530 m; and (ii) a transmission line measuring 2,605 m equipped with a gate valve assembly, water meter and pressure gauge for measuring the incoming pressure into the filtration unit. The project involves the introduction of protected agriculture within the project area as well as in other areas across Dominica. In so doing, the scheme provides additional protection to the biodiversity of the adjacent Morne Diablotin National Park by addressing the potential encroachment of farmers operating in the Milton community into the national park, which lies at the foothills of the Morne Diablotin mountains in the agricultural region at the north-western side of the island.
Agroforestry and forest management (5Cs)	St Lucia	Aged cocoa plantations have been replanted and new areas within forest zones have been established to support small farmers, increasing their livelihoods and income while reducing deforestation. Specific project activities include: (i) purchasing cocoa seedlings and fruit tree seedlings; (ii) purchasing fertilisers and other agro-chemicals; and (iii) acquiring one hydro-meteorological station.

Identifying and promoting the use of more resistant crop varieties		Scientists at the International Centre for Tropical Agriculture (CIAT) and the University of the West Indies have been testing and identifying various fruit and vegetables, tree crops and tubers that demonstrate a high tolerance to drought and heat stress. Most of this work has taken place in Jamaica and Trinidad. Similarly, research scientists at the USDA Tropical Agricultural Research Station at Mayaguez, Puerto Rico, are developing dry bean germplasm lines with increased tolerance to drought, high temperatures and increased resistance to diseases such as common bacterial blight, root rot and common bean mosaic virus. The goal is to develop dry edible beans that require less water to grow. So far, two robust black-bean germplasm lines have been released with improved tolerance to heat, drought, common bacterial blight and bruchid pests.
Adoption of climate-smart technologies and innovations via aquaponics	Virgin Islands	Aquaponics is the combined production culture of fish and hydroponic plants in recirculating systems where aquaculture effluent provides most of the nutrients required by plants. The University of the Virgin Islands has developed a commercial-scale aquaponics system producing 4.5 million tonnes of tilapia annually, which is harvested at six-week intervals, as well as a variety of vegetables, including lettuce, which are harvested weekly. Because of its water-use efficiency, aquaponics has proven to be ideal for tropical, semi-arid environments. The system also does not require much arable land and avoids the water pollution issues associated with certain traditional forms of agriculture.
Building resilience through promotion of climate-smart agriculture practices	Puerto Rico	There has been growing interest in using organic agriculture as a climate-adaptation strategy in Puerto Rico. The total value of sales generated by farms selling organically produced commodities increased from US$40,000 to US$421,000 between 2007 and 2012. Organic agriculture is found to be more diverse, use fewer external inputs and consume less energy than industrial agriculture. Organic farming can increase organic matter content in soil and prevent nutrient loss, thus enhancing the water-retention capacity of soils. As a result, organic farming systems are considered to be less vulnerable to the effects of extreme weather conditions, such as drought and flooding, and emit fewer greenhouse gases as well as demonstrate a greater potential to sequester carbon than industrial agriculture. Diversified crops are also believed to improve resilience to a wide range of diseases and pests while providing mixed income streams.

Implications for scaling up climate adaptation solutions in priority agriculture value chains

This report has so far pointed to an uncertain future characterised by heightened climatic risks for agriculture value-chain actors in the Caribbean. Of the climate-adaptation initiatives operating throughout the region already, the majority are pilot projects and are usually limited in both scale and scope. To increase the region's resilience, training and curriculum development must be targeted throughout regional priority agriculture value chains, and solutions and best practices must be scaled up where possible. While this will require the development of new and innovative ideas, approaches and technologies, adaptation strategies should also consider and build on work already started where deemed feasible. The remainder of this section outlines a few areas that could serve as good entry points for intervention programmes in the Caribbean.

Technical cooperation

The forging of partnerships among donor and implementing organisations across regional, national and sub-national scales will be instrumental in scaling up adaptation solutions in the priority agriculture value chains as well as providing significant and sustained support for the agriculture industry in general. As seen in this report, a number of external organisations support climate-compatible development in the Caribbean, including the World Bank, largely through its Global Environment Facility (GEF), the Organization of American States, the Canadian International Development Agency and the United States Agency for International Development. The UNDP, UNEP, UK Department for International Development (DFID), FAO, Inter-American Development Bank and United Nations Economic Commission for Latin America and the Caribbean (UNECLAC) are also very active in the Caribbean region. These partnerships can be built on and strengthened.

The forging of public-private partnerships, especially at the national and sub-national levels, will provide the space for innovation, capital investment and capacity building. State agencies are normally constrained due to a shortage of human capital and limited access to funding. Working with private-sector companies, civil society groups or NGOs that have solid experience working with agriculture value-chain actors can create invaluable opportunities for building resilience throughout the two priority value chains of fruit and vegetables and roots and tubers.

Strengthening the capacity of local communities and key value-chain actors to effect change may be a sustainable and cost-effective approach to replicating and scaling up community-based adaptation initiatives. The use of farmer field schools, for instance, has proven to be a very useful method in engaging local farming communities and transferring knowledge and best practices at the grassroots level. The development of technical training material in areas such as sustainable land husbandry, integrated pest management and agro-ecology can play a major role in building resilience in the agriculture sector in general.

Technical cooperation is needed around water, which has emerged as a cross-cutting issue that requires urgent attention from regional leaders. Water availability and access seem to be a major challenge for actors in the two priority value chains. And this situation is expected to get worse as the region's climate gets progressively warmer and drier. As such, there needs to be greater cooperation in tackling challenges related to the supply, demand and management of water resources throughout the region.

More cooperation is also needed around research and technology. While there are promising initiatives aimed at building climate resilience (including the identification and/or development of resistant crop cultivars), these projects are generally restricted to a limited number of crops and countries. Much more funding is needed in order for these initiatives to have a regional impact. Entire value chains need to be looked at as opposed to focusing on individual segments.

The retrieval, monitoring and management of scientific information and its dissemination to specific users in the agriculture value chain is integral to building resilience and supporting climate-smart farming practices. The timely provision of robust weather/climate information may help safeguard the livelihoods of thousands of rural farmers and their families and a host of other value-chain actors who rely on agriculture directly or indirectly for a living. While the CIMH has been partnering with the CCCCC and other agencies to enhance the provision of climate information services to the agriculture sector, significant knowledge asymmetries between regional states remain. Farmers across the Caribbean still farm with little to no access to climate information services.

Policy pathways

Many regional and national policies, plans and programmes are already targeted at the agriculture sector in response to the threats posed by climate change. The Regional Framework for Achieving Development Resilient to Climate Change defines the region's strategic approach for coping with, and building resilience to, these adverse effects. The Regional Framework is supported by an Implementation Plan that is designed to guide regional and national stakeholders to identify and prioritise actions that align with the Framework's strategic elements and goals. The Implementation Plan outlines several cross-cutting challenges that require more attention from regional policy-makers, including:

- closing information and evidence gaps;
- achieving gender empowerment;
- reducing disaster risk;
- building technical, financial and human capacity;
- improving information management and access;
- mobilising the private sector.

These challenges are in keeping with the findings of this desktop review. From all accounts, regional institutions such as the CCCCC are making good progress in most of these areas. Yet more emphasis needs to be placed on brokering strategic partnerships with private-sector bodies, especially at the national and sub-national levels. The mobilisation of the private sector can provide the space for innovation and the growth of local investments in climate-smart agricultural opportunities.

At the national level, the focus has been on mainstreaming climate-change adaptation concerns and strategies into existing development plans and programmes as well as identifying and promoting actions to reduce the vulnerability of environmental and human systems to the impacts of climate change. A few areas that require further attention, however, are:

- resource mobilisation (which includes strengthening the capacity of local entities to mobilise and manage adaptation funds);
- risk financing mechanisms that are suitable to the local realities in the Caribbean;
- identification of climate investment opportunities;
- identification and revision of national laws that present barriers to innovation in the agriculture sector e.g., those that restrict household rainwater harvesting or prioritise other sectors over agriculture in water allocation.

Opportunities for climate financing

This report shows that numerous opportunities exist for climate financing in the Caribbean agriculture sector, especially with regards to the two priority value chains. A methodological approach, field examples, and lessons for designing policies to provide smart support to climate finance and related initiatives in development country context has been documented (Ajayi *et al.*, 2012). At the production stage, the requirements for fruit and vegetables are quite different from roots and tubers. Given the shorter growing cycle and higher perishability of most fruit and vegetables, flexible unsecured loans are needed during times of shocks. Since the majority of fruit and vegetable farmers in the Caribbean are smallholders, microfinancing would be appropriate. Roots and tubers generally require slightly greater investment in time and resources. As such, farmers who specialise in the cultivation of roots and tubers could benefit significantly from longer term agricultural investment financing schemes. In general, the creation of locally managed funding pools that participating members of a cooperative can draw on during times of emergency would be beneficial to both groups of farmers. There are also numerous opportunities for private-sector investment in climate-smart technologies, such as precision irrigation systems and biodegradable mulching materials.

As discussed, the Caribbean agriculture sector is quite susceptible to the damaging effects of extreme weather events such as drought, excessive rains, storms and hurricanes. Crop risk insurance schemes could therefore be a useful mechanism for managing risks associated with farming. While numerous pilot programmes have been developed over the years, targeted at smallholder farmers in developing countries, the majority of funds from these schemes have largely benefited farmers in developed countries, with only a small percentage of global premiums being paid out to developing regions. In the latter case, this insurance is mostly accessed by larger, more affluent farmers. While insurance should not be seen as a panacea to the risks and uncertainties farmers are facing, it provides a useful tool for spreading risk throughout the agriculture sector. As such, more effort is needed to develop risk insurance schemes that are effective, culturally sensitive and sustainable. Again, the requirements for farmers that specialise in fruit and vegetables could very well differ from farmers who cultivate roots and tubers.

As one moves through the product cycle, the situation becomes more similar for the two priority value chains. In general, greater investment should be placed in the following areas:

- improved post-harvest management technologies;
- improved use of water resources, involving enhanced capture, storage and use of water in agro-processing activities and use of grey water where possible, which may result in significant cost savings and improved efficiency;
- identification, promotion and development of energy-efficient systems;
- identification and promotion of recycling and upcycling opportunities among value-chain actors.

Conclusions and key messages

The overarching purpose of this report is to support the implementation of CTA's regional business plan for the Caribbean with the provision of data and information that can assist regional capacity-building efforts targeted at key agriculture value-chain actors. Emphasis was placed on the threats climate change poses to the production of two priority value chains in the Caribbean – fruit and vegetables and roots and tubers. These two value chains are very important in terms of sustaining household food security and reducing poverty throughout the region, and provide an important source of income for thousands of smallholder and medium-scale farmers and their families. As demonstrated in this report, climate change has serious implications for the Caribbean in general, given the region's dependence on the agriculture sector and its efforts to develop sustainable agriculture-based value chains targeted at local and overseas markets. Any major fall in the production of either fruit and vegetables or roots and tubers could therefore stem, if not reverse, past efforts to reduce poverty in the region. The situation could be made worse as climate change interacts with other stressors, such as changes in population, poor farming practices, underlying socio-economic inequities and poverty, and environmental degradation. Taking stock of these threats is therefore critical for the viability of the Caribbean agriculture sector. It is also a necessary first step towards the formulation and successful implementation of regional and national policies and programmes aimed at effectively reducing poverty and achieving sustainable food security through the promotion of viable, climate-smart agribusiness enterprises.

The report evaluated some of the current and potential impacts of climate change on the two aforementioned priority value chains. Considerable scientific evidence indicates that the Caribbean is already experiencing a changing climate regime. For instance, since the 1950s the region's climate has gotten progressively warmer, with a marked increase in the number of very hot days and very hot nights across the Caribbean Basin. There is a general consensus within the regional climate science community that the regional climate will get progressively warmer and drier over the course of this century (Taylor *et al.*, 2007; Stephenson *et al.*, 2008; Gamble *et al.*, 2010; Campbell *et al.*, 2011; Taylor *et al.*, 2012). In addition to these trends, a marked increase in hurricane and tropical storm activities in the region has been observed since the mid-1990s, which may be linked to longer term anthropogenic climate change.

The damage and cost implications of these trends and predictions are immense. The report demonstrates that any significant fluctuation in the region's climate (especially in terms of mean surface temperature and rainfall) will certainly have adverse effects on the region's agriculture sector and the millions of people who rely on the sector for a living. Predicted shortages in available water resources across the majority of the Caribbean and increases in evapotranspiration present a direct challenge for the open-field, rain-fed cropping systems that dominate the region's agricultural landscape, not to mention the impending threats that extreme weather events such as hurricanes pose to agricultural production and farming infrastructure. The root and tuber and fruit and vegetable value chains are particularly susceptible to these climatic shocks given their sensitivity and exposure to a range of climate-related hazards, as illustrated by recent hurricanes, floods and droughts. In addition, the projected long-term changes in temperature and rainfall are likely to have a negative effect on regional agricultural production if measures are not put in place soon. While this seems to be a likely scenario for the Caribbean, regional farmers are operating with only limited information on the likely impacts of future climate change and of the potential of available cultivars to withstand these changes.

Another specific objective of this report was to identify critical stages where various actors in the fruit and vegetable and root and tuber value chains are most vulnerable to climate-change effects. Future changes in the region's climate will certainly have an impact on various groups of value-chain actors more so than others. The large differences in vulnerability seem to be a function of an individual's position along the value chain (which, to some extent, determines their degree of exposure to climate-related impacts) and are compounded by wider societal, cultural, agronomic and economic factors, such as gender, poor farming practices, limited access to climate-smart solutions and technologies, and disparities in wealth. This report shows, for instance, that Caribbean farmers are particularly vulnerable to climate-related impacts given the nature of their farming systems and the socio-economic landscape

in which they operate. The bulk of farmers in the Caribbean operate on small (sometimes fragmented) farm holdings and their cropping systems are normally labour intensive and rain-fed. In addition, many of these farmers operate with limited access to extension support services and financial assistance. As the climate becomes less predictable, these vulnerabilities are going to become more pronounced.

Other value-chain actors, such as traders, distributors and agro-processors, are also vulnerable to climate-change impacts. Traders are considered vulnerable to both short-term climatic shocks and longer term climatic stresses. Impacts from hurricanes and tropical storms, for instance, usually result in shortages in local food supplies, which negatively affect traders' ability to meet the demands of their clientele directly after a storm. This problem is usually compounded by limited or a lack of storage facilities. In general, the report shows how interconnected these value-chain actors are with each other. Indeed, if farmers are affected negatively, this will generate negative feedback throughout the entire value chain. Any disruption in local food production will result in the loss of income for other value-chain actors as well as farmers, and will also lead to an increase in food prices in the domestic market, which poses a threat to regional food security.

The report also looks at the policy environment shaping climate-change action and discourse in the Caribbean and the financing mechanisms that are available to regional agriculture value-chain actors to help them respond effectively to the threats posed by a changing regional climate. In terms of policy, an array of past and ongoing regional policies and programmes have direct linkages with agriculture and will be influential in boosting the sector's capacity to mitigate and adapt to climate change. Despite the strides made, asymmetries remain between countries in terms of national, institutional and individual capacities. One of the biggest challenges is the absence of accurate and up-to-date data on climate-related impacts and sector-specific vulnerabilities.

A number of funding sources are available for climate change-related activities within the regional agriculture sector. A significant portion of these funds are available through multilateral financing mechanisms. With key institutions like the CCCCC and the Caribbean Development Bank gaining accreditation with the Green Climate Fund, the region is now in a better position to increase its share of available global climate financing. Utilising climate finance effectively, however, requires strong regional and national institutions capable of effectively deploying money and overseeing the implementation of high-impact initiatives. There is also a need to tap into other financial resources, such as bilateral agreements. Further, financing may come from the private sector, including the regional business community and philanthropic organisations.

The final objective of the report was to identify the likely implications of these findings for the scaling-up of climate-adaptation solutions for the two regional priority value chains. Essentially, agriculture value-chain actors in the Caribbean face an uncertain future typified by heightened climatic risks. The bulk of climate-adaptation initiatives in the region are pilot projects that are limited in scale and scope. Training and curriculum development must be targeted to the regional priority agriculture value chains and climate-resilient solutions and best practices scaled up where possible. The forging and strengthening of technical partnerships and cooperation around climate financing, science and innovation, capacity development and the retrieval, monitoring and dissemination of relevant, up-to-date and accurate scientific information are integral to building resilience and supporting climate-smart farming practices in the Caribbean.

Crucially, we need to understand the enabling factors and constraints for mainstreaming climate-compatible development in the Caribbean. It is important to understand potential uptake for transformative change and technology transfer within the regional context, taking into consideration cultural practices and wider societal and environmental factors. It is instructive to note here that some of the main factors driving the vulnerability of agriculture value-chain actors in the Caribbean to climatic shocks are systemic. Any effort at offsetting climatic stressors will therefore have to address inherent weaknesses and inefficiencies in the sector, including the relatively short-term planning cycles practised by some farmers, lack of innovative and sustained climate financing opportunities, the inadequate resources available to support implementation of actions, absence of suitable and cost-effective technologies and innovations, and the limited involvement of the private sector in the industry region-wide. While risk transfer mechanisms provide part of the solution to the bigger problem facing the regional agricultural sector, they cannot serve as a substitute for good, on-farm risk-management techniques, sound production and farm management practices and investments in climate-smart technologies.

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